

Fabrication Of Ten Utility Acoustic Modems, Version 2.0 For The Modem Pool At WHOI

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LONG-TERM GOALS

The long term goal of this program relates to the implementation of Autonomous Ocean Sampling Networks (AOSN) that include combinations of vehicles, stationary instruments and data collection centers such as buoys or cabled nodes.

OBJECTIVES

The objectives of this program include providing underwater acoustic modems for use by other programs that are also sponsored by ONR. Potential users include MIT Sea Grant and Ocean Power Systems.

APPROACH

The approach for the Modem Pool is to fabricate, document and distribute complete acoustic modems for use by other groups. The hardware design and software development is funded by other programs. The acoustic modems being built for the Modem Pool on this project are the new Micro-Modems, which were developed using ONR funds during the very shallow water and surf-zone mine countermeasure program (VSW/SZ MCM). This is a modification to the original grant to allow more modems to be built (16) and to keep the hardware current with the state-of-the art. The work is being done at the Woods Hole Oceanographic Institution. Mark Johnson is the hardware designer, Lee Freitag is the systems engineer and Dan Frye is the Modem Pool manager.

The capability of the current version of the acoustic modem includes a basic set of functions:

1. Single-duplex, bi-directional communication using the WHOI Frequency-Hopping Standard at 40 or 80 bps. (Interoperability Standard).
2. Hardware support for the 12.8-17 kHz frequency band.
3. Transparent or command-driven serial interface.
4. Low-power sleep mode with wake-up on serial input.

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Overview of Operation

When power is applied to the Micro-Modem it automatically starts both the acoustic receiver and the serial port handler. The Micro-Modem takes user data in one of two formats from its serial port, breaks the data into individual 32 byte packets, adds header information, encodes the data, and then modulates it to passband for transmission. The modem is single-duplex, i.e. it uses one band for both transmission and reception. Thus during a transmission the receiver is temporarily disabled.

The WHOI Frequency-Hopping Standard was developed as a simple, but robust physical layer definition that provides inter-operability between different modems and also provides a low-rate fallback link for any modem, in much the same way as the 300 bps telephone modem standard does.

The modulation method used by the standard is binary (one-of-two) frequency-shift keying (FSK) with frequency hopping. Two data rates are available, the raw (uncoded) rates are 80 and 160 bits per second, while the coded rates are 40 and 80 bits per second. The symbol durations corresponding to the two rates are 12.5 and 6.25 milliseconds respectively. At the 80 symbol per second rate the separation between frequencies is fixed at 160 Hz. At the 160 symbol per second rate the separation is 320 Hz.

The total bandwidth occupied by the signals is defined by the hopping patterns and the rate, but it is approximately 4 kHz. The upper band edges are calculated based on this and listed in Table I. The fast rate uses 14 frequencies divided into 7 pairs. The slow rate uses 26 frequencies divided into 13 pairs. One pair is used to transmit one bit of information and each of the pairs are used according to a pattern defined by the hopping pattern. The default pattern simply steps through the frequencies sequentially.

The hopping patterns are simple and allow several user pairs to operate simultaneously in the same area depending upon range, multipath and the selected data rate. For any two users there will only be a collision (both users occupying the same pair) once per pass through the hopping pattern.

While frequency hopping is inherently bandwidth inefficient, in addition to supporting several users it has two key advantages.

1. **Multipath Avoidance.** Only one frequency pair is used at a time and thus the multipath has time to die out before a particular frequency is used again. Table I shows the channel clearing time for each rate. In general the channel clearing time for the faster rate is adequate in shallow water (less than 30 meters). In deeper water the multipath may extend much longer and require that the low rate be used.
2. **Interference Immunity.** Long baseline navigation systems and external tracking systems use relatively narrow-band pings with high source levels. While the acoustic modem signal may occasionally occupy the same frequency as the pinger, it will do so only occasionally. When this does happen the error-correction coding takes care of the short period that the signal is corrupted.

A more complete description of the physical layer of the modem including data segmenting, packetization, coding and modulation may be found in Multi-User Frequency-Hopping Underwater Acoustic Communication Protocol which is available for download at <ftp://ael/whoi.edu/pub/fhfsk.pdf>.

Table I. Signal Parameters for Band B.

Raw Rate sps	Tones Used	Lowest Freq. Hz	Highest Freq. Hz	Clearing Time sec
160	14	12800	16960	0.0375
80	26	12800	16800	0.150

PHYSICAL DESCRIPTION

The complete modem includes the electronics and transducer plus an optional pressure case. Thus, the system may be supplied for use within existing pressure housings or as a stand-alone unit connected to the user device via an underwater cable.

The Micro-Modem electronics consists of two boards. The main board includes digital signal processor, serial ports, analog conversion and signal conditioning. The second board contains the power amplifier, T/R network and pre-amplifier. The two boards are connected via headers on each board. The board set is designed to fit into a two inch diameter pressure case. The board set is shown in Figure 1.



Figure 1. Micro-Modem board set.

WORK COMPLETED

The work completed to date includes the manufacture of 16 Micro-Modem board sets and a total of 8 packaged units with transducers and pressure cases. In addition, documentation for both wiring and software have been developed for the users. A simplified version of the user interface developed for the VSW/SZ application has been written and documented for the users.

RESULTS

The Micro-Modem has been used as a transmitter in a number of applications to date. These include the MCM program [1], a NOPP-sponsored Portable Observatory project in Massachusetts Bay [2], a NAVO-sponsored mooring system [3], and the NSF-sponsored Ultramoor long-term mooring project [4].

Modems from the ONR Utility Modem Pool were also used for a number of applications this past year, including an earlier deployment of Ultramoor, a deployment as part of a meteorological instrumentation system for Kernel Blitz in April of 2001, and an installation on an MIT Odyssey vehicle during the GOATS 2000 experiment. A plot showing the test geometry during GOATS and acoustically transmitted vehicle positions is shown in Figure 2.

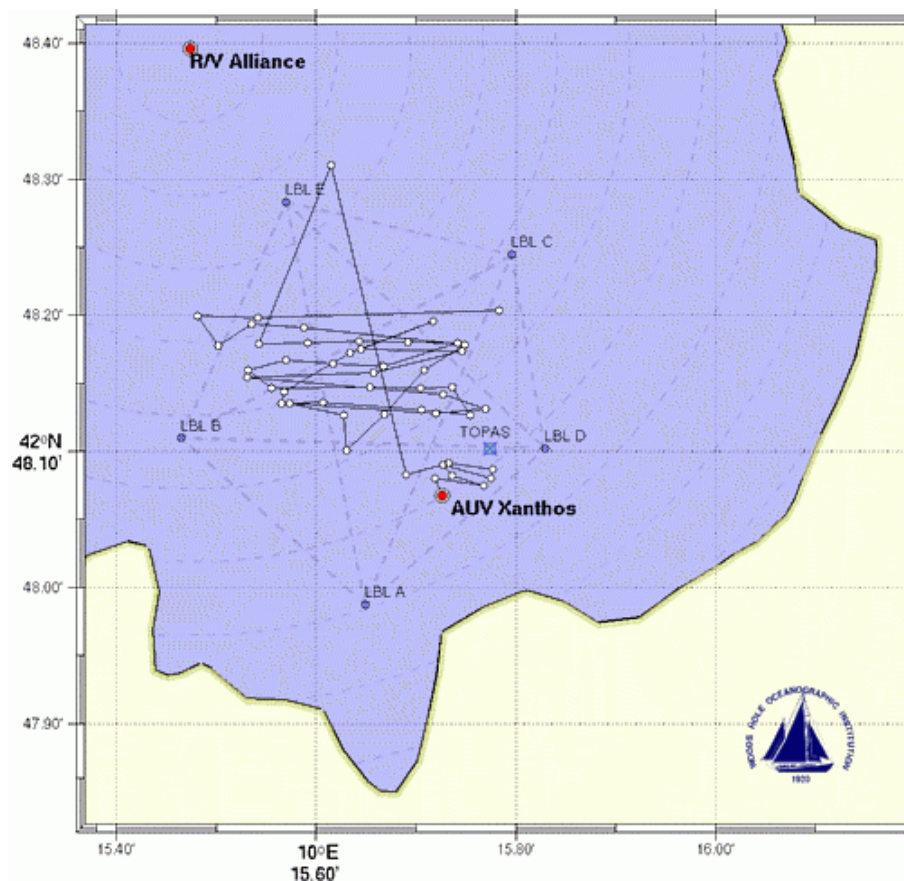


Figure 2

IMPACT/APPLICATIONS

The impact of the Micro-Modem is potentially significant because it is both small and inexpensive. Applications that may make use of it include very small vehicles and compact instrumentation systems. For example, remote data units deployed on the sea floor and clustered around a central data collector (either on the bottom or at the surface) can be used with the Micro-Modem.

TRANSITIONS

The near-term transition is done by loaning equipment to users who would otherwise not have access to an acoustic communication system. The expected loan period is several months to one year. Additional transitions may occur as part of future ONR funded programs, including the pre-planned product improvements (P3I) for SAHRV.

RELATED PROJECTS

1. WHOI, Real time current measurements. PI: Dan Frye. Sponsor: NAVO, Grant# N00014-94-10346.
2. WHOI, Ultramoor, NSF, Grant# OCE9810641.
3. MIT Sea Grant, GOATS experiment. PI: Henrik Schmidt. Sponsor: ONR.
4. WHOI Meteorological instrumentation, Physical Oceanography Department. PI: Robert Weller. Sponsor: ONR (Secretary of the Navy).
5. WHOI, NOPP Portable Coastal Observatory project, Grant#N00014-98-1-0816.

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- [1] Freitag, L., M. Johnson, M. Grund, S. Singh and J. Preisig, "Integrated Acoustic Communication and Navigation for Multiple UUVs," *Proc. Oceans 2001*, Honolulu, HI, submitted, 2001.
- [2] Frye, D., B. Butman, M. Johnson, K. von der Heydt and S. Lerner, "Portable coastal observatories," *Oceanography*, Vol. 13, No. 2, pp. 24-31, 2000.
- [3] Koski, P., J. Ware, S. Cumbee and D. Frye, "Data telemetry for ocean bottom instrumentation," *Proc. Oceans 2001*, Honolulu, Nov. 2001.
- [4] Frye, D., D. Peters, N. Hogg and C. Wunsch, "ULTRAMOOR: A 5-year current meter mooring," *Proc. Oceans' 2000*, Providence, RI, Vol. 2, pp. 1097-1102, Sept. 2000.

PUBLICATIONS

WHOI Micro-Modem Specifications and User Manual, ONR Modem Pool Version. Woods Hole Oceanographic Institution Technical Report. Available at <ftp://aetl.whoi.edu/pub/mmspec.pdf>